Evaluating Soil Improvers for Enhancing Soil Quality in Shallot Production

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Abstract. Applying effective soil improvers is expected to enhance soil quality and optimize the growth and productivity of shallots. This study aimed to evaluate the most effective soil improver treatment for improving the soil quality and shallot yield. The research was conducted in Poncokusumo, Malang Regency, East Java, Indonesia, using a Randomized Complete Block Design (RCBD) with two factors. The first factor was soil improver (P), consisting of four levels: B1 = vermicompost, B2 = compost, B3 = biochar, and B4 = goat manure. The second factor was variety (V), consisting of three levels: V1 = Batu Ijo, V2 = Tajuk, and V3 = Super Philip. Each treatment combination was replicated three times, resulting in a total of 36 experimental units. Growth measurements were taken every 10 days from 14 to 54 days after planting (DAP), including plant height, the number of leaves, and the number of tillers. Yield parameters included the number of bulbs, fresh bulb weight per plant, bulb diameter, and total yield. Analysis of variance indicated that no significant effect of soil improvers was observed, whereas variety has a significant impact on both growth and yield parameters. The Tajuk variety showed superior growth, while Batu Ijo produced the highest overall yield.

1 Introduction

Shallots are an important horticultural commodity that has high economic value and is widely used in the culinary industry. To achieve optimal yields, it is essential to maintain good soil quality and fertility, including properties such as organic matter content, texture, structure, pH and adequate nutrient availability. However, with time and improper cultivation practices, soils can suffer a decline in quality and fertility. Factors such as soil erosion, excessive use of chemical fertilizers and pesticides and lack of soil maintenance can lead to soil degradation characterized by reduced microbial activity and Carbon (C) and Nitrogen (N) reserves in the soil [1-4]. In general, maintaining soil organic carbon content above 2% is considered necessary to support sustainable crop growth.

To overcome the above problems, soil improvers have become the focus of attention in modern agriculture. Soil improvers are synthetic or natural, organic or mineral materials in

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solid or liquid form that can improve the physical, chemical and biological properties of soil (MOA No.01 of 2019). Therefore, soil improvers aim to improve soil physical properties such as permeability, porosity, water holding capacity, cation exchange capacity and soil structure, increasing the availability of nutrients [5-7]. Soil microbial activity, reducing acidity and increasing soil microbial activity [8-11]. As well as plant physiological growth by supplying plant nutrients, including micronutrients and physicochemical properties [12,13]. Thus, providing a better environment for root development by improving soil structure [14-16]. Several previous studies have shown that soil improvers have significant positive effects on overall soil health compared to unamended soils, such as increasing organic matter, N and potassium content and preventing leaching of nutrients in groundwater [17].

Soil improvers can be classified as natural or synthetic, depending on their source and degree of processing. Natural soil improvers are derived directly from organic, biological, or inorganic materials without significant alteration in their composition, while synthetic improvers are processed materials that have undergone chemical or structural modifications [18]. Although many studies have demonstrated the benefits of soil improvers for improving soil health and crop performance, research specifically focusing on shallot cultivation remains limited. Shallots differ from other crops in their root morphology and nutrient uptake behavior, which may result in distinct responses to soil improvement treatments. Therefore, it is necessary to evaluate various types of soil improvers and shallot varieties to identify effective combinations that enhance soil quality and yield. This study aims to determine the most effective soil improver for improving soil quality and productivity of different shallot varieties grown under field conditions in East Java, Indonesia.

2 Research Methods

This experimental design uses a randomized complete block design (RCBD) with two factors. The first factor is soil conditioner (B), consisting of four levels, and the second factor is variety (V), composed of three levels. The treatment was repeated 3 times, so that 36 experimental units were obtained. First Factor is Soil Improver (B), which consists of Vermicompost (B1), Compost (B2), Biochar (B3), and Manure (B4). Second Factor is Shallot Variety (V), which consists of Batu Ijo (V1), Tajuk (V2), and Super Philip (V3).

Table 1. Combination of Soil Improver Treatment (B) with Variety of Shallots (V)

Treatment	V1: Batu Ijo	V2:Tajuk	V3: SuperPhilip
B1 : Vermicompost	**B1V1:** Vermicompost+Batu Ijo	**B1V2:** Vermicompost+Tajuk	**B1V3:** Vermicompost+Super Philip
B2 : Compost	**B2V1:** Compost+Batu Ijo	**B2V2:** Compost+Tajuk	**B2V3:** Compost+Super Philip
B3 : Biochar	**B3V1:** Biochar+Batu Ijo	**B3V2:** Biochar+Tajuk	**B3V3:** Biochar+Super Philip
B4 : Goat Manure	**B4V1:** Goat Manure+Batu Ijo	**B4V2:** Goat Manure+Tajuk	**B4V3:** Goat Manure+Super Philip

2.1 Research Implementation

2.1.1 Soil and Fertilizer Analysis Test

Before planting, a complete analysis of the soil before and after the study and fertilizer was carried out to determine the pH, nutrient content contained in the soil and fertilizer.

2.1.2 Preparation of Planting Media

The growing medium used in this experiment consisted of a mixture of soil improvers. The soil was mixed with soil before the soil improver, and the soil was sieved with a sieve with a density of 0.5 cm, then the media mixture was put into polybags measuring 40 x 40 cm. Each treatment combination consisted of 6 samples for a total of 216 polybags.

2.1.3 Onion Seed Preparation

The shallot seeds used in this study were Batu Ijo, Tajuk and Super Philip varieties. The seeds that will be planted have relatively the same size, and at the end of the seed, a slight cut is made using a cutter to help accelerate the growth of shoots.

2.1.4 Planting

The shallot seed bulbs used are 5-10 g in size. Before planting, the bulbs were cut by 1/3 of the tip first, and then the bulbs were planted with the cut tip facing up. In one polybag, one shallot bulb was planted.

2.1.5 Plant Maintenance

Plant maintenance includes watering and controlling pests, diseases and weeds. Plant watering is carried out at the beginning of planting in the morning or afternoon, because at the time of planting, it is not yet the rainy season. Pest and disease control is done by spraying fungicides and insecticides, while weed control is done manually until the plants are 50 DAP old.

2.1.6 Supplemental Fertilization

Supplementary fertilization is done after 15 DAP (day after planting) by applying N fertilizer at a dose of 1/3 of the recommended dose. Fertilizer is applied by spreading it on the plots.

2.2 Variable Measurement

Measurement of variables was done nondestructively. Measurements for growth variables began at the age of 14 dap to 54 dap with an observation interval of 10 days, while yield variables were carried out at harvest time. The measured growth variables include, Plant height (cm): measured from the base of the bulb to the tip of the highest leaf; number of leaves: count the green leaves; number of tillers: count the number of tillers formed; number of bulbs: count the number of bulbs on the plant; bulb weight per plant (g): the weight of all bulbs on the plant was calculated; bulb diameter: the diameter of each bulb was computed using a caliper; yield (t/ha): calculated harvest yield obtained. Supporting analysis is carried out to support the data obtained from the measurement of growth and yield variables, including chlorophyll analysis, carried out during the active vegetative phase and using a spectrophotometer.

2.3 Data Analysis

The research data were analyzed following the Randomized Complete Block Design (RCBD) procedure. F test to determine the interaction between factors and the effect of each factor. Tukey 5% comparative test to determine differences between treatments.

3 Result and Discussion

Analysis of variance showed a significant interaction between soil improvers (B) and shallot varieties at 54 days after planting (DAP). Soil improvers had a significant effect only at this stage, while varieties affected plant height at all observation times except 54 DAP. The combination of goat manure + Batu Ijo produced the tallest plants. Among varieties, Batu Ijo consistently showed higher plant height compared to Tajuk and Super Philip. These results indicate that varietal traits play a greater role in determining plant height than soil improvers.

3.1 Plant Height

Based on the results of analysis of variance on plant height, it shows that the treatment combination between soil improvers and varieties interacts at the age of 54 DAP. Separately, the application of soil conditioner showed a significant effect at the age of 54 DAP, while the use of shallot varieties showed a very significant effect at all observation ages except at the age of 54 DAP.

Table 2. Average Plant Height as a Result of Interaction between Soil Improvement Treatments and Shallot Varieties at the Age of 54 DAP.

Treatment	**Plant Height (cm) / Age (DAP)**
	54 DAP
B1V1	44.92 b
B1V2	37.72 a
B1V3	42.94 ab
B2V1	44.79 b
B2V2	38.63 ab
B2V3	38.48 ab
B3V1	44.02 ab
B3V2	39.07 ab
B3V3	39.63 ab
B4V1	44.94 b
B4V2	37.64 a
B4V3	42.94 ab
Tukey 5%	6.83

Notes: Numbers followed by the same letter indicate no significant difference in the 5% Tukey test.

The combination of manure treatment with the Batu Ijo variety showed relatively higher plant height compared to other treatment combinations (Table 2). Furthermore, the Batu Ijo variety showed higher plant height growth than the Tajuk and Super Philip varieties (Table 3).

Table 3. Average Plant Height Due to Application of Soil Improvers and Varieties of Shallot at Various Ages of Observation.

Treatment	Plant Height/Age (DAP)			
	14	**24**	**34**	**44**
B1(Vermikompost)	24.42	36.41	41.73	42.93
B2(Compost)	23.78	36.14	42.32	43.23
B3(Biochar)	22.71	35.93	41.59	41.64
B4(Manure)	23.15	36.24	42.50	43.71
V1(Batu Ijo)	26.37 b	41.93 c	47.32 b	47.90 b
V2(Tajuk)	21.45 a	31.68 a	38.16 a	39.56 a
V3(Super Philip)	22.74 a	34.92 b	40.63 a	41.17 a
Tukey 5%	2.13	2.78	2.93	3.15

Notes: Numbers followed by the same letter in the same column indicate no significant difference in the 5% Tukey test.

3.2 Number of Leaves

ANOVA showed no interaction effect between soil improvers and varieties on leaf number at any growth stage. Soil improvers had no significant effect, while varieties significantly affected the number of leaves from 34 to 54 DAP. Tajuk produced the highest leaf number, suggesting superior vegetative vigor. The absence of significant effects from soil improvers may be due to similar nutrient release rates and sufficient baseline soil fertility at the experimental site.

Table 4. Average Number of Leaves due to Application of Soil Improvers and Varieties of Shallot at Various Ages of Observation.

Treatment	Number of Leaves/ age (DAP)				
	14	**24**	**34**	**44**	**54**
B1 (Vermicompost)	14.84	28.98	39.69	48.13	44.75
B2 (Compost)	14.78	26.42	36.67	41.17	38.50
B3 (Biochar)	15.92	31.06	43.33	47.33	45.97
B4 (Manure)	15.33	28.08	42.47	48.72	47.19
V1 (Batu Ijo)	15.58 a	29.29 a	34.46 a	39.23 a	35.50 a
V2 (Tajuk)	14.33 a	27.08 a	46.19 b	50.96 b	50.50 b
V3 (Super Philip)	15.74 a	29.53 a	40.98 ab	48.83 ab	47.79 b
Tukey 5%	2.92	6.01	8.93	10.28	8.30

Notes: Numbers followed by the same letter in the same column indicate no significant difference in the 5% Tukey test.

3.3 Number of Tillers

No interaction was observed between soil improvers and varieties on the number of tillers. Soil improvers did not significantly affect tiller production, whereas varieties significantly influenced it at all stages. Tajuk produced the highest number of tillers throughout the observation period. This reflects genetic differences in vegetative growth potential, while the soil's inherent fertility likely minimized the observable effects of the soil improvers (Table 5).

Table 5. Average Number of Tiller as a Result of Soil Improver Application and Shallot Variety at Various Ages of Observation.

Treatment	Number of tillers/age (DAP)				
	14	24	34	44	54
B1(Vermicompost)	6.51	9.25	10.71	11.92	13.44
B2 (Compost)	6.19	8.17	9.31	10.19	10.97
B3 (Biochar)	7.06	9.64	11.42	11.97	12.00
B4 (Manure)	6.28	8.78	10.72	11.75	12.53
V1 (Batu Ijo)	5.58 a	7.69 a	8.00 a	8.17 a	8.33 a
V2 (Tajuk)	7.00 b	9.73 b	12.27 b	13.38 b	14.96 b
V3 (Super Philip)	6.94 b	9.46 ab	11.35 b	12.83 b	13.42 b
Tukey 5%	1.19	1.81	2.13	2.34	2.45

Notes: Numbers followed by the same letter in the same column indicate no significant difference in the 5% Tukey test.

3.4 Diameter of Bulbs, Number of Bulbs per Clump, Fresh Weight per Clump, Dry Weight per Clump and Yield.

Based on the results of the analysis of variance on the yield components, it shows that no significant interaction between soil improvers and varieties was observed for yield-related traits, including bulb diameter, bulb number, fresh bulb weight, dry bulb weight, and total yield. Soil improvers (B) had no significant effect on any yield parameter, while varieties showed highly significant differences. Batu Ijo achieved the largest bulb diameter, highest bulb weight, and greatest yield (21.4 t/ha), whereas Tajuk produced more bulbs but with a smaller size and lower yield. These findings suggest that genetic characteristics of the varieties dominate yield performance, and that soil improvers under the given conditions did not contribute substantially to yield improvement (Table 6).

Table 6. Average Diameter of Bulb, Number of Bulbs per Clump, Fresh Weight per Clump, Dry Weight per Clump and Yield.

Treatment	Diameter of Bulb	Number of Bulbs	Fresh Weight	Dry Weight	Yield
B1 (Vermicompost)	2.31	13.39	85.64	76.16	19.04
B2 (Compost)	2.19	10.97	74.50	65.86	16.47
B3 (Biochar)	2.27	12.00	81.66	72.27	18.07
B4 (Manure)	2.30	12.47	85.81	76.56	19.14
V1 (Batu Ijo)	2.91 b	8.33 a	95.30 b	85.75 b	21.44 b
V2 (Tajuk)	1.93 a	14.96 b	70.24 a	61.21 a	15.31 a
V3 (Super Philip)	1.96 a	13.33 b	80.18 ab	71.15 ab	17.79 ab
Tukey 5%	0.16	2.44	17.35	17.14	4.29

Notes: Numbers followed by the same letter in the same column indicate no significant difference in the 5% Tukey test.

The application of soil *improvers* has no effect on the growth and yield of several varieties of shallots. Growth parameters include plant height, number of leaves, number of tillers, and yield parameters include bulb diameter, number of bulbs per clump, wet weight per clump, dry weight per clump and yield, showing relatively better growth occurs in the Tajuk variety, while the yield component shows relatively higher yields in the Batu Ijo variety.

The growth and development of shallots are influenced by internal and external factors, including the nutrients needed by the plant [18]. Growth, as an increase in weight and size of plants as a result of the formation of new structural elements, is strongly influenced by the availability of nutrients. This is because the availability of nutrients is needed from the beginning of plant life to stimulate growth. The availability of nutrients for plants can be fulfilled by providing soil improvers, because soil improvers contain nutrients in a form that is available to plants.

The availability of nutrients in the soil is related to the process of soil amendment breakdown that occurs. The incorporation of soil *improvers* into the soil will stimulate the most beneficial organisms to carry out the breakdown and enzymatic processes of the soil *improvers*. Thus, the addition of soil *improvers* to the soil will increase the number and activity of soil microorganisms that function to increase soil aggregation, which in turn will ensure better aeration so as to improve the availability of nutrients for plants [4, 8].

This is related to shallot rooting, which is relatively shallow and does not spread, namely 40 cm in the top soil, so that to get optimal rooting, shallots need a rooting medium with a balanced aeration capacity and media water storage. An optimal rooting medium requires sufficient pore space and oxygen diffusion for root respiration. This condition enhances carbohydrate and nutrient translocation to the root zone, supporting shallot growth. Furthermore, increased soil aggregation will increase nutrient uptake by plants. This is because good aggregation can not only provide sufficient N, P and K, but can also make unavailable forms of nutrients into available forms so that plants absorb nutrients more easily. However, in this study, the application of four soil improvers that were tried did not show significant differences, meaning that any type of soil improver applied to shallots can affect growth and yield.

Plant productivity is not only determined by external factors, but also by the ability of plants to adapt to their growing environment. The use of different varieties in one planting environment will provide an overview of the adaptability of varieties. High shallot growth is shown by the Tajuk variety, while the high-yielding component of shallots is shown by the Batu Ijo variety. This condition is due to agroecological factors that are quite influential on the emergence of a variety, even though the location is not from the area of origin of the variety. The Batu Ijo variety gave a yield of 21.44, Tajuk 15.31 and Super Philip 17.79 t/ha. These results were not much different from the production ranges mentioned in the variety descriptions, except for the Batu Ijo variety, which showed higher yields than the variety descriptions.

The difference in yield of the three varieties tested is due to the different genetic traits of the varieties. Different genetic traits cause differences in response between the three varieties to environmental conditions, so that growth activity and yield are also different. This is shown by the diversity of plant appearance, because plant varieties have different sensitivities to nutrient availability. This condition can be seen from growth such as plant height, number of leaves and number of tillers that are different. Different varieties will produce a large number of tillers very quickly, and some others will be slow and few, so as to produce maximum production. The number of tillers formed is not only influenced by genetic factors but also determined by the level of soil fertility. In the potential of superior varieties, such as the number of tillers, to plant production at the time of planting is still influenced by the interaction between varieties and the conditions in which they grow.

The Batu Ijo variety shows the genetic potential of a variety in accordance with agroecological conditions, especially at the research location, namely Poncokusumo Village, Malang Regency. In addition to genetic factors, the environment around the plant greatly influences the production of the plant. The ideal environment around the plant can produce high photosynthate, so that the translocation of photosynthate to generative organs, especially bulbs, is also high. This can be seen from the high yield of Batu Ijo varieties.

4 Conclusion

Shallot cultivation in Poncokusumo Village, Malang District, shows strong potential based on the results of this study. The application of soil improvers did not show a significant effect on plant growth or yield, indicating that soil fertility in the area may already be sufficient to support shallot production without additional amendments. In contrast, varietal differences played a major role in determining growth and yield performance. Among the tested varieties, Batu Ijo achieved the highest yield, 40.04% higher than Tajuk and 20.52% higher than Super Philip, while Tajuk demonstrated superior vegetative growth in terms of leaf number and tiller formation. These results suggest that selecting suitable varieties has a greater impact on productivity than the use of soil improvers under similar conditions. For farmers, this finding highlights the importance of choosing high-performing varieties like Batu Ijo for higher yields or Tajuk for strong vegetative growth. Future research should explore the longer-term effects of soil improvers under varying soil conditions to better understand their cumulative benefits on shallot cultivation.

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